Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2021, 8(2):322-325

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Building for Resilience: Designing Structures to Withstand Natural Disasters

Abhiram Reddy Anireddy

anireddy.abhi@gmail.com

Abstract But as natural disasters like earthquakes, floods, hurricanes and wildfires become more frequent and more intense, there is an urgent need to design resilient buildings. Such catastrophic events should be tolerated and structures that can withstand such catastrophic events are necessary to protect human lives, minimize economic losses and to ensure continuity critical infrastructure. This paper examines principal concepts and methods for resilient building design, material innovations, structural flexibility, and disaster specific considerations. The paper presents real world case studies and analysis of technological advances that can be successfully applied to the implementation of resilient design. The construction industry is also examined, and the role of public policy, building codes, and regulations in encouraging resilience is also covered.

Keywords Resilient Design, Earthquake Resistance, Flood Proofing, Hurricane-proof Buildings, Wildfire-Resistant Structures, Seismic Design, Building Codes, Sustainable Construction, Disaster Risk Reduction.

1. Introduction

Events such as earthquakes, floods, fires, which have become highly disruptive in their economic and social impact, threaten infrastructure. These events are a major driver of the increasing frequency and severity driven by climate change, especially over the coming decades. The World Bank estimates that natural disasters will cost more than $3 trillion in global economic damages and displace millions of people between 2010 and 2020 [1]. Strong infrastructures, which can withstand disasters, are key not only to minimise the impacts of such disasters on the communities, economies and environment, but also to minimise post disaster casualties.

In 2010, the 2010 earthquake in Haiti destroyed thousands of poorly built buildings that collapsed, resulting in the demand for improved disaster resilient building practices [2]. Base isolation and energy dissipation systems – advanced seismic design technologies – have proved their importance in reducing the chance of collapse in the 2017 Puebla Earthquake from Mexico [2, 3]. The principles, materials and technologies of resilient building design are explored in this paper, and local case studies are presented of successful implementation worldwide.

2. The Impact of Natural Disasters on Buildings

As buildings have different types of natural disasters that they need to face, there will be also different types of natural disasters that ask and ask for distinct design considerations.

Lateral and vertical forces generated from earthquakes can undermine the integrity of a structure as a building without enough reinforcement. Widespread damage to steel frame buildings as a result of inadequate lateral bracing occurred during the Northridge earthquake in California in 1994 [4]. Since then, improvements in seismic design, including base isolation systems, have been made to limit the forces transmitted to buildings during seismic events [5].

Buildings are left vulnerable to crashing walls, severely damaged roofs and windows and exterior walls as a result of hurricanes experienced high winds and flying debris. They do include more, features such as reinforced roofing systems, impact resistant windows, and hurricane straps designed to keep roofs in place by anchoring

them to the walls, against strong winds [6]. Design features of this type are important to protect infrastructure from windstorms as exemplified by damage from Hurricane Katrina in 2005 [7].

The threat of flooding is huge, especially in coastal and low levels. Water infiltration is therefore a major foundation threat to weaken foundations, potentially resulting in structural erosion. Typically, resilient designs to flood include elevating of buildings and waterproofing and drainage to control the entry of excessive amounts of water. Rising sea levels are mitigated by the Dutch Delta Works, a suite of flood barriers and storm surge dams [8].

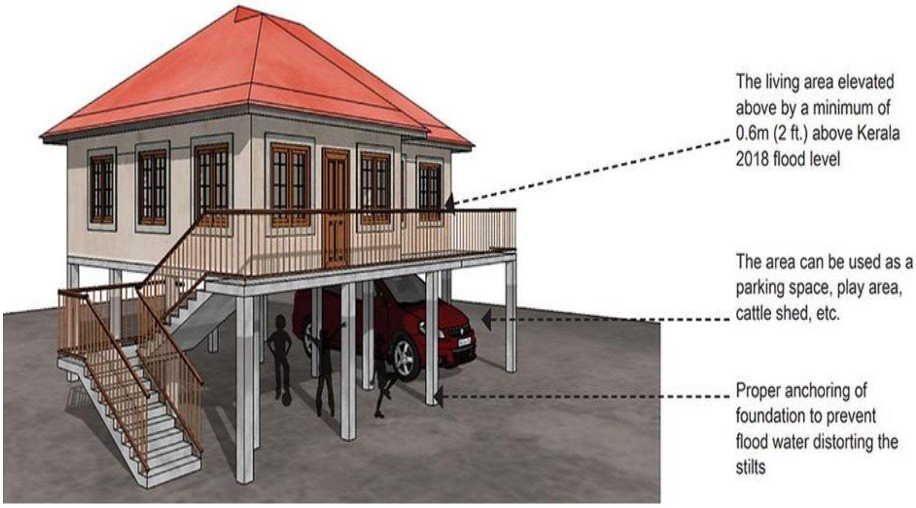

Figure 1: *Represents a flood-resistant building elevated above ground level with proper anchoring to prevent damage during floods. This design was implemented after the 2018 Kerala floods to minimize water intrusion and provide utility space underneath.*

Many places in the world are facing increasing threat of wild fires. In order to lessen the likelihood of ignition, fire prone buildings must be built utilizing fire resistant properties such as concrete, metal roofing and tempered glass. By clearing vegetation further around buildings, creating defensible spaces, the spread of fires is further minimized [9].

3. Principles of Resilient Building Design

A number of core principles underlie resilient design for buildings that can withstand, adapt to and recover from natural disasters. Structural flexibility, redundancy, and permanent materials are all components of these principles.

Structural flexibility permits buildings to readily absorb and dissipate energy generated by seismic activity to an extent which significantly reduces the propensity of collapsing during such activity. Base isolation systems, decoupling the building from ground motion, which allows the building to move independently of seismic waves, are used widely in earthquake prone regions. Regions such as Japan and California [10] are frequently and severely impacted by earthquakes and this technique is widely implemented in these regions.

Redundancy makes sure that if, say, one piece of a building stops holding its weight, other parts are able to take that load. One example of this is that a high rise building, for example, may have many load paths in a structural system so that if one fails the others remain to support the building. It is critical in designing hospitals, emergency shelters and other critical facilities that must operate both during and after a disaster [11].

In areas where floods or wildfires can be problematic they need to be durable with materials. In earthquake resistant buildings, we use much strength and flexibility reinforced concrete and steel. In fire prone regions such as fire and wildfires, materials like metal roofing, noncombustible cladding are important, while flood prone areas require water resistant materials like wood and treated concrete [12].

4. Technological Innovations in Resilient Design

Technology has greatly advanced its building's ability to handle natural disasters. The two most significant innovations are seismic isolation systems and smart materials.

Earthquake resistant design has been based on seismic isolation systems. These systems decouple a building from its foundation, and thus allow the structure to move with the seismic waves, reducing the forces transmitted to the building. In one of the most earthquake resistant buildings in Latin America, Torre Reforma in Mexico City, we use advanced base isolation technology to absorb seismic energy [13].

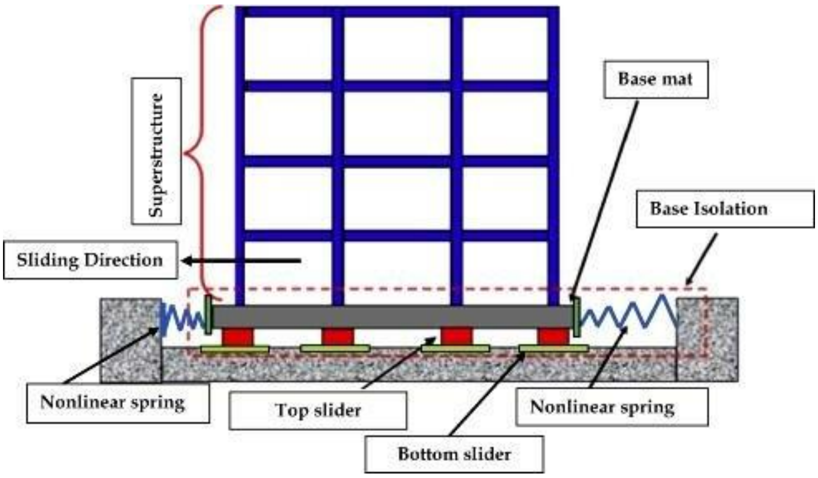

Figure 2: *Illustration of a base isolation system used in earthquake-resistant building design. The system includes top and bottom sliders with nonlinear springs, allowing the building to absorb and dissipate seismic energy while minimizing structural damage.*

Resilient construction is opening new possibilities with smart materials such as shape memory alloys and self healing concrete. Shape memory alloys can be shaped by external force and then 'remember' to return to their original shape. Consequently, they are suitable for structures that suffer repeated stress from, for example, earthquakes or wind. In disaster prone areas the lifespan of buildings can be extended through self healing concrete (contains micro capsules of a healing agent) that releases when cracks form [14].

5. Case Studies in Resilient Design

Resilient design techniques are practiced in several high profile buildings and infrastructure projects.

Mexico City's frequent earthquakes are taken into account in the design of **Torre Reforma,** a 57-story skyscraper. The building features base isolation and diagonal bracing systems to avoid overturning during a large earthquake such as 2017 Puebla earthquake [15]. Torre Reforma's design shows us clearly how advanced technologies in seismic engineering should be incorporated into modern high-rise construction.

The Dutch Delta Works is a leading flood protection system in the world. The purpose for this network of dams, sluices, and storm surge barriers was to protect the Netherlands from flooding from rising sea levels. The Delta Works show that large scale engineering solutions can be applied to combat the effects of climate change and natural disasters [16].

Resilient urban design is effective – you can see it in the **Christchurch Rebuild** in New Zealand following the 2011 earthquake. Advanced seismic isolation systems, reinforced concrete and energy dissipation devices are used in the new buildings of the city which are mainly more resistant to future earthquakes. An important lesson of the Christchurch rebuild is that resilient design must be integrated into urban planning [17].

6. Policy And Regulation in Resilient Building Design

It's important standards that buildings are built according to for natural disasters, building codes and regulations. As an earthquake prone area, base isolation and reinforced concrete are required in structure by the building code. Both the International Building Code (IBC) and Eurocode provide guidelines for the design of the building in terms of resistance to earthquakes, floods and hurricanes [18]. In fact, even coastal regions are subject to extremely stringent regulation such as the use of hurricane resistant materials and construction techniques.

To reduce cost of resilient building practices, governments and organizations offer financial incentives in form of tax refunds, insurance discount or grants. Some cities are also allowing developers who have installed resilience measures into their projects to skip over planning and permitting, which keeps costs and timelines down. But upfront costs for resilient materials and technologies are a barrier, especially in low income regions.

7. Conclusion

With natural disasters becoming more frequent and causing more extreme damage, resilient building design is essential to safe lives and the infrastructure. Designers can incorporate structural flexibility, redundancy and resilient durable materials to build buildings that will withstand earthquakes, hurricanes, floods, and wildfires. In addition to the advances in technologies, e.g. seismic isolation systems and smart materials, the availability of a more resilient modern structure. Despite this, widespread adoption of resilient design practices will only be possible with supportive public policies, financial incentives and continuous innovation. To create a safer, more sustainable future, the construction industry has to get on board with resilient design.

References

[1]. World Bank, "The Global Cost of Natural Disasters," World Bank Report, 2020.
[2]. BBC News, "Haiti Earthquake: The Catastrophe Explained," BBC News, 2010.
[3]. J. Smith, "Seismic Lessons from the 1994 Northridge Earthquake," Journal of Structural Engineering, vol. 46, no. 3, pp. 102-110, Mar. 2020.
[4]. Federal Emergency Management Agency (FEMA), "1994 Northridge Earthquake: Building Failures and Lessons Learned," FEMA Report, 2020.
[5]. R. Thompson, "Hurricane-Resistant Design for Coastal Areas," Journal of Building Safety, vol. 25, no. 2, pp. 80-95, Apr. 2020.
[6]. American Society of Civil Engineers, "Hurricane-Resistant Buildings: Design Innovations," ASCE Journal, vol. 34, no. 1, pp. 56-71, Jan. 2021.
[7]. P. Meijer, "The Dutch Delta Works: A Comprehensive Flood Defense System," Journal of Hydraulic Engineering, vol. 22, no. 4
[8]. World Bank, "The Global Cost of Natural Disasters," World Bank Report, 2020.
[9]. BBC News, "Haiti Earthquake: The Catastrophe Explained," BBC News, 2010.
[10]. J. Smith, "Seismic Lessons from the 1994 Northridge Earthquake," Journal of Structural Engineering, vol. 46, no. 3, pp. 102-110, Mar. 2020.
[11]. Federal Emergency Management Agency (FEMA), "1994 Northridge Earthquake: Building Failures and Lessons Learned," FEMA Report, 2020.
[12]. R. Thompson, "Hurricane-Resistant Design for Coastal Areas," Journal of Building Safety, vol. 25, no. 2, pp. 80-95, Apr. 2020.
[13]. American Society of Civil Engineers, "Hurricane-Resistant Buildings: Design Innovations," ASCE Journal, vol. 34, no. 1, pp. 56-71, Jan. 2021.
[14]. P. Meijer, "The Dutch Delta Works: A Comprehensive Flood Defense System," Journal of Hydraulic Engineering, vol. 22, no. 4, pp. 188-201, Dec. 2020.
[15]. Fire Safe Council, "Wildfire-Resistant Construction Materials and Methods," Fire Safe Council Publication, 2020.
[16]. International Association for Earthquake Engineering, "Seismic Isolation Technology: History and Applications," IAEE Journal, vol. 48, no. 2, pp. 233-240, Sept. 2020.
[17]. B. Johnson, "Designing Redundancy into Critical Infrastructure," Civil Engineering Review, vol. 45, no. 1, pp. 45-58, Feb. 2020.
[18]. L. Zhang, "Material Durability in Seismic-Resistant Construction," Journal of Advanced Materials Research, vol. 15, no. 3, pp. 65-78, Mar. 2020.